Simulation and Construction of Shashlyk-Type Ecal for the EIC

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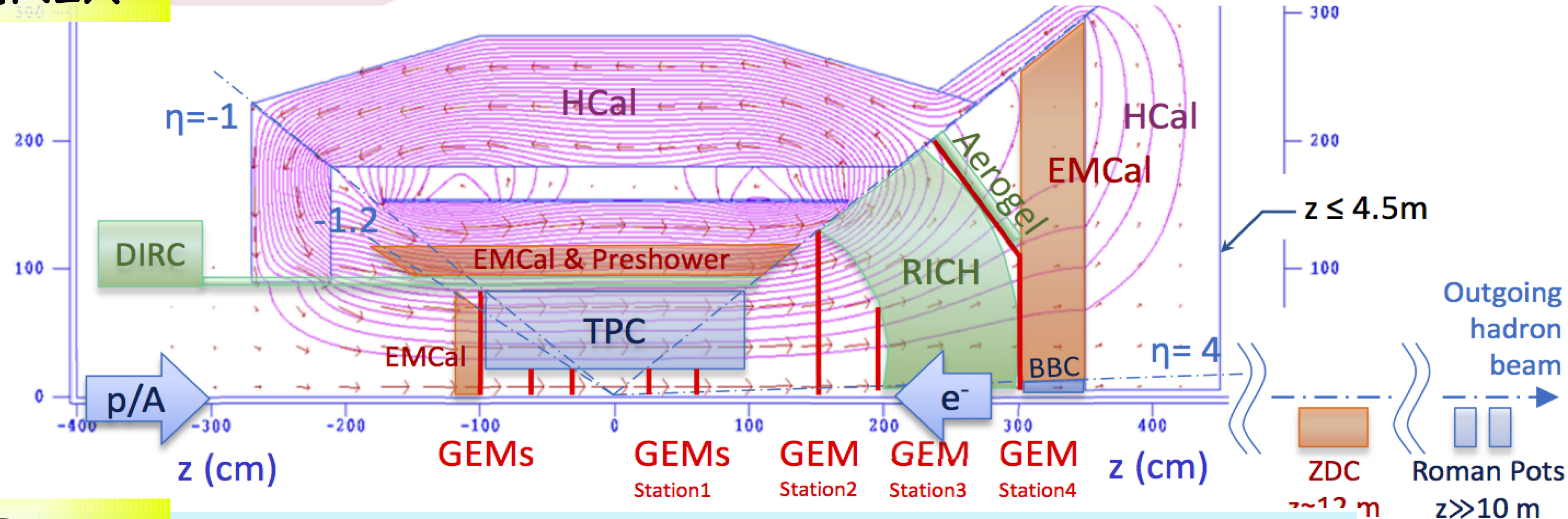
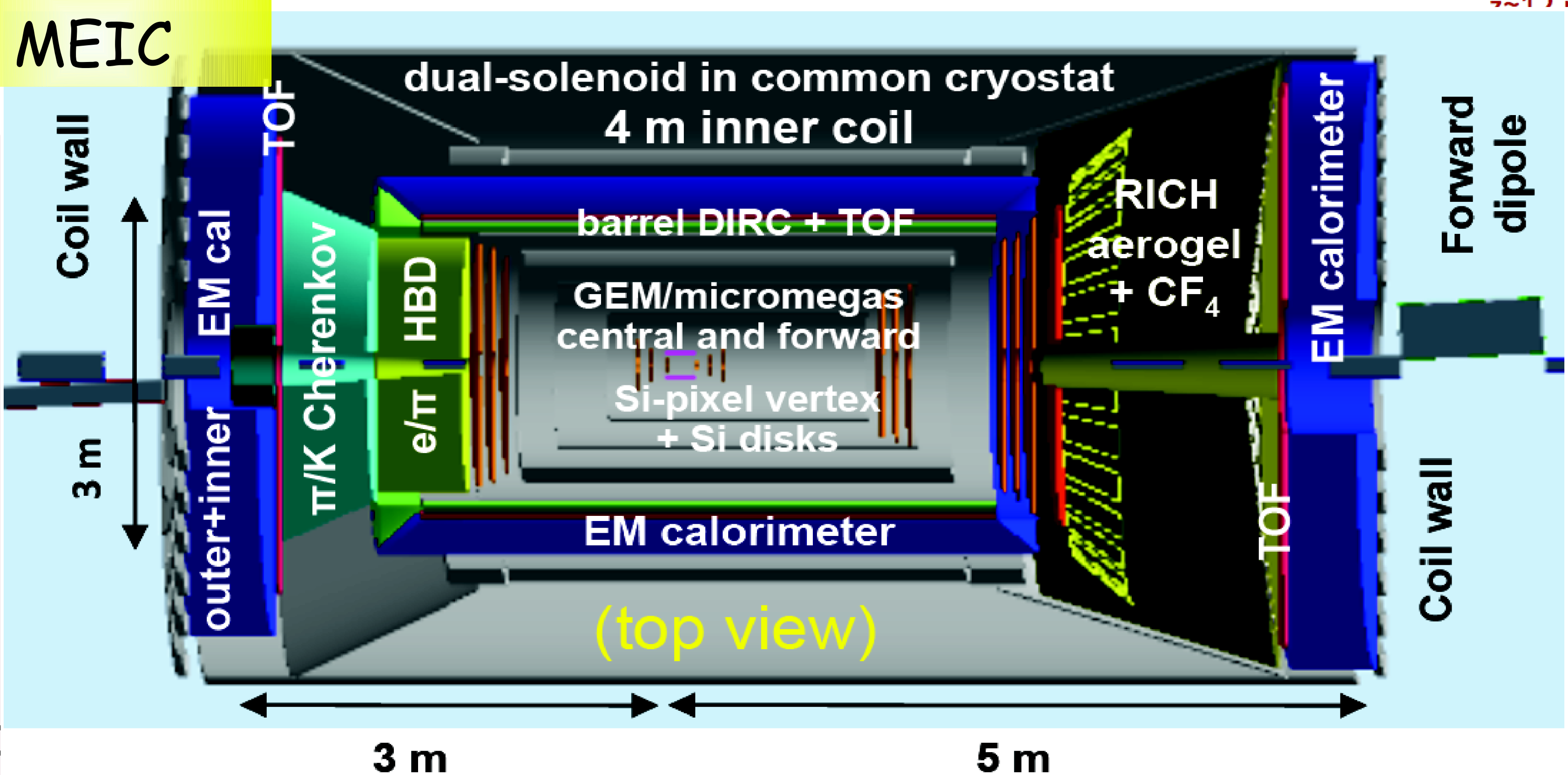
Ecal Needs for EIC

ePHENIX



MEIC



Ecal Needs for EIC

1. Electron-direction Ecal: need (1-2)%/sqrt(E) for inner radial region, top choice is crystal; (5-6)%/sqrt(E) for outer radial region.
2. Hadron-direction Ecal: need (12-15)%/sqrt(E) for ePHENIX or (5-6)%/sqrt(E) for MEIC.
3. Central Ecal: need 12%/sqrt(E), need to be radially compact (25cm), current top choice is W-scifi.

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Radiation background at colliders: must sustain up to 10^6 rad

Material	ρ g/cm^3	X_0 cm	R_M cm	λ_I cm	n refrac.	τ ns	peak λ nm	light yield	Npe /GeV	rad	δE/E
Crystals											
NaI(Tl)	3.67	2.59	4.5	41.4	1.85	250	410	1.00	10^6	10^2	$1.5\%/E^{1/2}$
CsI	4.53	1.85	3.8	36.5	1.80	30	420	0.05	10^4	10^4	$2.0\%/E^{1/2}$
CsI(Tl)	4.53	1.85	3.8	36.5	1.80	1200	550	0.40	10^6	10^3	$1.5\%/E^{1/2}$
BGO	7.13	1.12	2.4	22.0	2.20	300	480	0.15	10^5	10^3	$2\%/E^{1/2}$
PbWO4	8.28	0.89	2.2	22.4	2.30	15/60%	420	0.013	10^4	10^6	$2.0\%/E^{1/2}$
LSO	7.40	1.14	2.3		1.81	40	440	0.7	10^6	10^6	$1.5\%/E^{1/2}$
PbF2	7.77	0.93	2.2		1.82	Cher	Cher	0.001	10^3	10^6	$3.5\%/E^{1/2}$
Lead glass											
TF1	3.86	2.74	4.7		1.65	Cher	Cher	0.001	10^3	10^3	$5.0\%/E^{1/2}$
SF-5	4.08	2.54	4.3	21.4	1.73	Cher	Cher	0.001	10^3	10^3	$5.0\%/E^{1/2}$
SF-57	5.51	1.54	2.6		1.89	Cher	Cher	0.001	10^3	10^3	$5.0\%/E^{1/2}$
Sampling: lead/scintillator											
SPACAL	5.0	1.6				5	425	0.3	2×10^4	10^6	$6.0\%/E^{1/2}$
Shashlyk	5.0	1.6				5	425	0.3	10^3	10^6	$10\%/E^{1/2}$
Shashlyk(K)	2.8	3.5	6.0			5	425	0.3	4×10^5	10^5	$3.5\%/E^{1/2}$

Possible Use of Shashlyk Ecal for EIC

1. Electron-direction Ecal: need (1-2)%/sqrt(E) for inner radial region, top choice is crystal; (5-6)%/sqrt(E) for outer radial region – shashlyk may be the best choice
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Module shape: all do not need to be projective, however

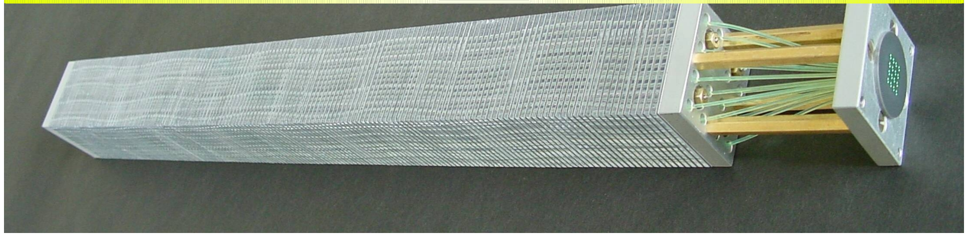
– central: must be projective for sPHENIX

– electron- and hadron-direction Ecals, a projective design will help with PID performance.

Snapshots of Shashlyk Ecal Technology

- thin layers of absorber stop particles while thin scintillator layers samples the shower signal
- light guided out by WLS fibers
- radiation hard (10^6rad), more cost effective than crystals such as LSO, energy resolution can reach 5%/sqrt(E) or even lower.

IHEP, COMPASS Shashlik, 2010



Used by COMPASS, KOPIO experiments, and ATLAS, ALICE, CMS upgrade

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- Technology relatively mature, but construction expertise is dominated by IHEP&ITEP (Russia). Only a couple of US groups have constructed Shashlyk modules (e.g. ALICE — Wayne State U., U. of Iowa)
- scintillator parts by injection molding and lead sheets by stamping, mold and tooling cost ~$45k, dominate prototyping cost
- difficult to construct projective-shape modules
- requires intensive manual labor during assembling process

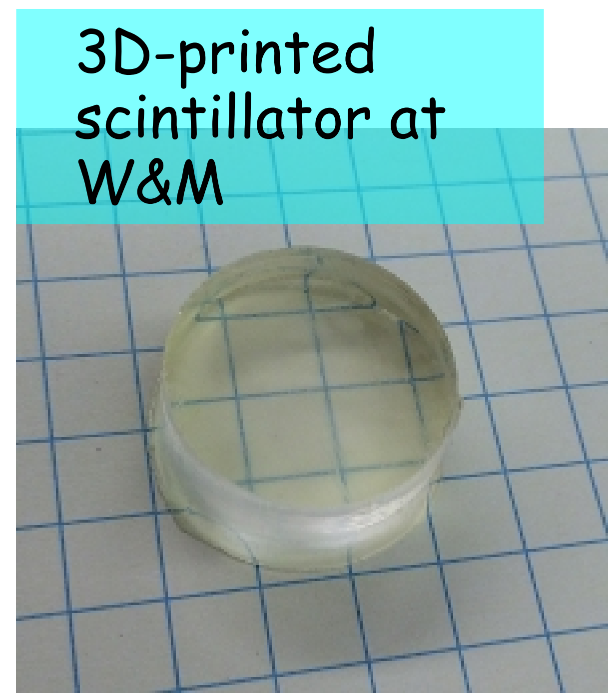
Our Focus for the first year

- Study preliminary design of shashlyk Ecals for EIC's outer electron and hadron Ecals, look into central Ecals.
- Look into possible re-use of existing or planned Shashlyk modules for EIC
- To gain knowledge and hands-on experience with testing shashlyk module components, focusing on testing 3D-printed scintillators

The "New" Component — 3D Printing

- Three existing 3D printing methods:
  - FDM
  - Resin-printing (polyjet)
  - metal printing

- We have already experimented with Polyjet-printing scintillators [G. Ron (Hebrew U.), W. Deconinck (W&M)]
  - Published results show plausible light yield (30% of commercial polysterene-based scintillators, currently improving compound design, comparable to commercial, need more study)
  - Also need data on optical transparency, mechanical strength, stability, radiation hardness



http://arxiv.org/abs/1406.4817

Potentials of 3D Printing

- fast and cost-effective prototyping;
- "easy" construction of projective shape modules;
- possible simplification of assembly process.

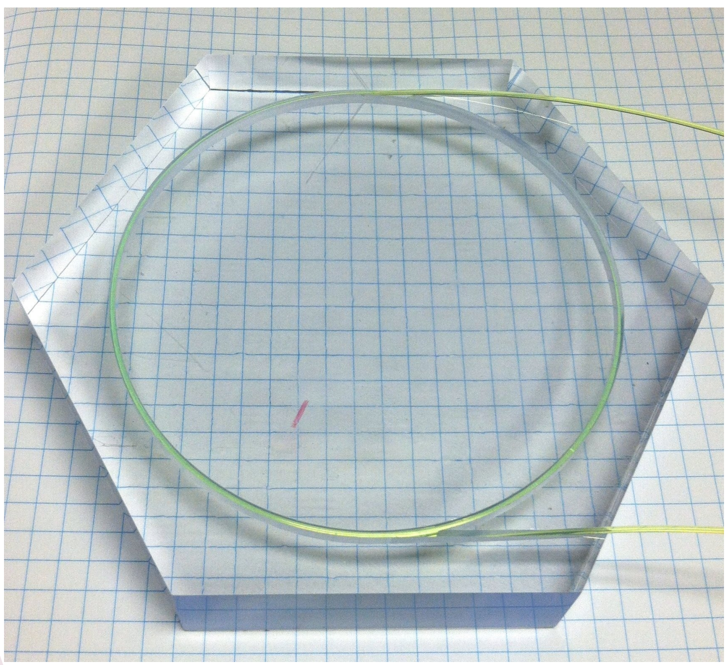
Test Plan for the First Year

- Obtain 3D-printed scintillator samples from Stratasys(Isarel), or made in-house at W&M
- Study light yield, transparency, mechanical properties (<u>compressive strength</u>), radiation hardness → revise compound formula and iterate
- *[Many of these studies are valuable for shashlyk module construction (quality screening of parts) regardless of whether 3D-printed sci works]*

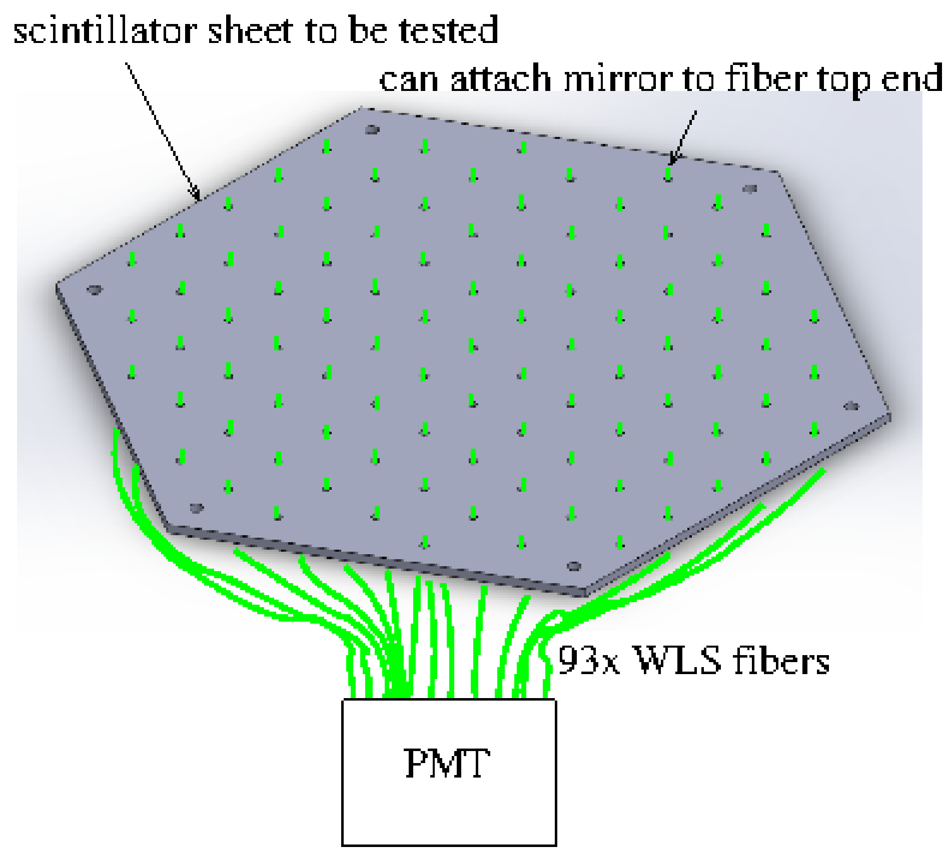
Test Plan for the First Year

- For mechanical testing: simple shape first, then shashylk components

- SoLID Preshower samples 20-mm (regular scintillator) tested at UVa, 2 vendors/bases – polysterene, phenylethene; will also test PVT-based



- Shashlyk components (1.5mm)



Will also study 3D-printed light guides using t-glase (a commercially available "optical quality" material), useful for light guides with complicated shape.

Budget

Item	cost
5 Eljen EJ-205 shashlyk sheets	$1,570
5 Beijing HE-Kedi shashlyk sheets	$1,000*
10 lead layers (Kolgashield) for the combined mechanical test	$800
Simple-shape scintillators as references (Eljen)	$1,000*
Light guides as references (Eljen)	$1,000*
Two scintillator bars (Eljen) for triggering the cosmic test	$1,400
Readout PMTs for the cosmic test (2 R11102)	$800
Other material and supply	$2,000
Travel	$1,000
One quarter postdoc support (incl. 28% F.B.)	$17,910
Graduate student, one-half A.Y. stipend	$19,158/2=$9,579
Total Request (direct only)	$38,059
Total Request (including 58% UVa F&A cost)	$60,133

- The postdoc will focus on simulation/design, lead the radiation hardness test, and guide the graduate student;
- From other UVa resource: FDM/t-glase for printing light guides; make Tungsten-filled FDM filament for printing absorber sheets.

Future Plan

- Prototyping for EIC's Shashlyk Ecal and test its performance, but whether 3D printing can be used will depend on results from the first year.